HANDBOOK

OF

Electricity in Medicine

BY

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(Paris)

TRANSLATED BY

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Surgeon to the
London Skin Hospital

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TRANSLATOR'S PREFACE

It has been well said that the man who has learned two languages possesses two souls. Still more truly may it be asserted, that he who has studied a science from the different points of view of two schools of thought, possesses a double understanding of his subject.

In the past, we have been greatly indebted to the school of French electrology, the school of *du Bois Reymond* and *Duchenne,* of *Apostoli* and *d'Arsonval.*

I trust I am doing a service to the English-speaking race, by introducing to its notice the more recent work of the French electro-therapeutic school, so ably summarized by *Dr. Guilleminot.*

W. DEANE BUTCHER.

Ealing, 1906.

PREFACE

Of all the subsidiary branches of medicine, Medical Electricity is the one which has made the greatest advances during the last few years.

Static electricity, and the Galvanic and Faradic currents have long been used for treatment. Recently, however, other forms of electrical energy, high frequency currents, sinusoidal currents, undulatory currents and others, have been introduced, and their therapeutic value abundantly proved. To these may be added the luminous and caloric radiations, the X-rays, and forms of radiations with every variety of wave length, from the slow vibrations of the Hertzian waves, up to high frequency currents, and the rapid oscillations of ultra-violet light.

Medical radiology, of which Röntgen radiology is but a branch, has considerably extended the domain of the medical electrician. The use of the newer radiations cannot be dissociated from electrical practice, practically because these radiations are usually generated by some form of electrical apparatus, and theoretically because all transverse oscillations of the ether are in reality electrical phenomena. *Maxwell's* electro-magnetic theory of light receives fresh confirmation every day.

The medical electrician, therefore, must be as well acquainted with radiant electricity as with current electricity.

His knowledge, however, must not end here. It is not enough to be an electrician and an expert operator. He must also be a master of physical biology. All vital processes are connected with electric phenomena,—osmosis,

alterations in surface tension, ionisation, the various chemico-physical processes connected with assimilation and catabolism, the functions of nutrition and cell motion, are all accompanied by the production of electricity. They are occasioned by differences of potential which may be demonstrated experimentally.

If the progress of science finally enables us to master this force, which is the very essence of life, and to subjugate it, as steam has been subjugated to the service of mankind, we shall have ready to our hands the most potent curative agent ever imagined to modify the evolution and ameliorate the condition of living beings.

Unfortunately we have not yet arrived at this stage. None the less is it important for us to study all the facts which demonstrate the production of electricity by living tissue. Quite recently a new group of phenomena has been discovered, which if they are confirmed by further investigation, will establish a new link between life and electricity. The newly discovered radiations of MM. *Blondlot* and *Charpentier* add one more evidence of the fact that all perturbation of living tissue is accompanied by a difference of electrical potential, and creates around it a field of irradiation. Without anticipating discoveries still in a nebulous state, we may assert that medical electrology should embrace the study of animal electrogenesis which touches so nearly our very conception of life.

The practitioner who endeavours to employ the various forms of electric energy without a knowledge of the laws which govern them, is but an artisan working by rule of thumb, incapable of improvement, and always liable to failure.

Each year brings to us a long procession of new discoveries. Medical sciences cannot afford to await maturity before being formulated. As new materials accumulate in the laboratory, the whole of the raw material of past knowledge must be thrown into the furnace, and our scientific and medical theories must be recast.

I present this work therefore as a synthesis of our knowledge concerning the different forms of electrical energy. It has been written under the powerful impulse of *Prof. Bouchard*, and of a school which has done good services in all branches of medicine.

Prof. Bouchard has ever insisted on the idea that medicine must tend more and more to take its place among the exact sciences. His observations have always been made "chiffres en main." He is physicist, chemist and mathematician in turn. Hence he has ever welcomed with enthusiasm the advances of biological physics and medical electricity.

It was in his laboratory that he foretold the part that X-rays would play in medicine, at a time when the X-rays were a mere object of curiosity. In a few months he demonstrated the wide rôle that Radioscopy was destined to play in medicine. The diagnosis of pleurisy, tuberculosis, aneurism, and the influence of the Hertzian waves were studied at a very early period in the laboratory of the Hôpital de la Charité.

These researches were continued when *Prof. Bouchard* placed in my hands the direction of the Laboratory. Some of my arrangements of apparatus have come into general use, such as my focus-tube stand with indicator of incidence, and my high frequency spirals. Others, such as the ortho-diagraph and the radio-cinematograph, have given useful results in the study of the thoracic organs.

It was in this laboratory, as long ago as 1860, that *Prof. Bouchard* did his work on the injurious effects of

coloured light of various wave lengths on the skin. Erythema pellagreux was identified as a solar erythema, and the "coup de soleil" was shewn to be the effect of violet radiations of short period.

Since then, whenever new facts or hypotheses have appeared, whether X-rays, high frequency currents, the radiations of *Blondlot*, or the radiation of radio-active substances, they have been received with enthusiasm, and subjected to a searching and critical examination. This work has been written with the dominant idea that medicine should draw as much assistance as possible from the accessory sciences, and more especially from physics. The theoretical study of electrical energy in the first part of my book should not discourage the student, nor should the study of physiological effects which I have treated in the second part. Both are the necessary prelude to the practice of electro-therapeutics.

With a knowledge of the science of electricity, the medical electrician will have a sense of intellectual satisfaction accompanying each step of his career, and will be duly armed, so as to be able to apply his art with precision and to mark out for himself new paths for conquest.

A mode of treatment which has given such unlooked for results in Cancer—the most incurable of all maladies, —may certainly expect further triumphs. There is much work to be done, and we may be certain that the future of Electro-therapeutics reserves for us still further surprises, and for humanity still greater services.

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CHAPTER I.—The Galvanic or Continuous Current.

INTRODUCTION

1. **Divisions.**—This work is divided into three parts.

Part I is devoted to the Physics of electricity and to questions of technique.

Part II deals with the physiological effects of the various forms of electricity, and with the other physical therapeutic agents in which electricity is the motive force.

Part III contains the medical portion of the work. The electro-diagnostic and electro-therapeutic treatment of each disease are treated together. Electro-diagnosis was formerly confined almost entirely to a single division of neuro-muscular pathology, but its scope has of late become greatly enlarged. The third part therefore forms a sort of compendium. Under each pathological condition are given firstly its diagnosis, and then the various methods of treatment.

PART I.

PHYSICS.

2. **Division of the subject.**—The medical electrician employs various forms of electrical energy.

Not only is electricity employed directly as a therapeutic agent, but it is also used as a generator of motion, heat, light, Röntgen rays and physico-chemical reactions. It is also used indirectly for such purposes as the generation of ozone. In the first part we propose to study briefly the physical facts which must be understood to enable us to utilise electrical energy in all its forms.

We shall take them in the following order:

I.—Galvanic Currents.

II.—Faradic Currents.

III.—Sinusoidal Currents.

IV.—High-frequency Currents.

V.—Electrostatics.

VI.—Röntgen Rays.

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CHAPTER IV.

HIGH FREQUENCY CURRENTS.

I. General Considerations.

122. **High Frequency.** The special physiological properties of the high frequency currents introduced by *Prof. d'Arsonval* place them in the front rank of therapeutic agents. They are alternating currents whose direction is reversed over a million times per second.

With the phonic wheel designed by *Sieur* we can get as many as ten thousand alternations per second. The physiological effects of such a current differ from those of an ordinary alternating current of low frequency, but we must increase the oscillations to a million or even a thousand million per second before we get what is generally understood by "high frequency." The period of such a current is of the order of a millionth to a thousand millionth of a second. The wave length is therefore a millionth or a thousand millionth of 300,000 kilometres; since 300,000 kilometres per second is the velocity of high frequency waves, of light waves, of X-rays, and of all transverse vibrations of the ether. This wave length of from 300 metres to 30 cm. or even less, brings the high frequency undulations into relation with the luminous waves. They prolong the scale of wave lengths at the infra-red end of the spectrum just as X-rays seem to prolong it at the ultra-violet end.

II. Production of High Frequency Currents.

123. **Production of the High Frequency Currents.**—*Hertz* first observed that high frequency currents are

generated by the disruptive discharge of a condensor in a circuit whose resistance is less than $\sqrt{\frac{4L}{C}}$; L being the coefficient of self-induction of the circuit and C the capacity of the condensor.

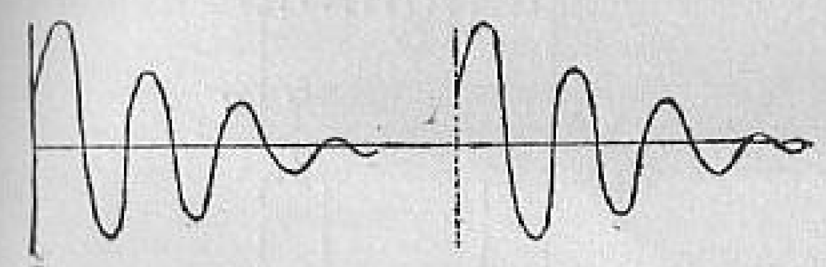

Fig. 22.

Fig. 22 represents the form of these oscillations, which die down with great rapidity. Their period is given by $T = 2\pi\sqrt{LC}$. Any reduction in C, the capacity of the condensor, or L, the self-induction of the circuit, diminishes the time of oscillation, and therefore the wave length of the radiations. In *Hertz'* detonator the capacity is very small. When L and C are both large, very long waves can be obtained.

124. **Choice of a Condensor for High Frequency Currents.**—*Tesla* employed a single *Leyden* jar for obtaining high frequency discharges; the usual arrangement, that employed by *d'Arsonval*, is shown in Fig. 23.

The inner coatings of two Leyden jars, BB', are connected to the rheophores of an induction coil P. A spark gap AA' is inserted between these jars. The outer coatings of the Leyden jars are connected together by a coil of copper wire CC' having a large coefficient of self-induction.

The resistance offered by the self-induction of such a coil to the passage of a variable current is enormous; so large indeed that a lamp mounted in parallel with it at DD' will

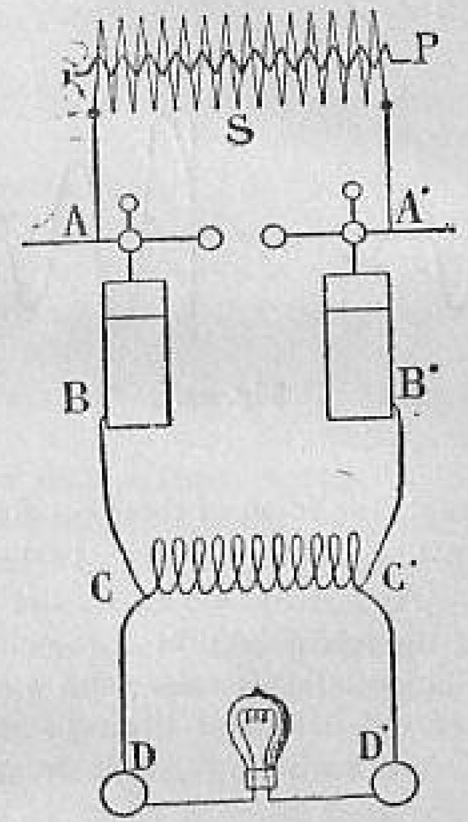

Fig. 23.—d'Arsonval's high frequency apparatus.

become incandescent, although its true resistance is infinitely greater than that of the coil.

Various types of condensors may be employed. Leyden jars, plate condensors, and oil condensors. It is possible to extemporise a condensor or to replace one which is damaged, by gumming tinfoil on a glass jar or a plate of glass, and immersing this in sand soaked with paraffin, or even in dry sand.

The spark gap should be enclosed in a box or thick case, to diminish the noise as much as possible.

125. **Electrical Source for High Frequency Apparatus.**—Any source of high tension electricity may be used, but an induction coil or an alternating current transformer is more convenient than a static machine.

For high frequency work, coils giving 10-inch to 18-inch sparks are required. These are supplied with special interruptors, having a condensor to suppress the "break" spark in the interruptor. Such condensors are indispensable for large coils, except when *Wehnelt's* electrolytic interruptor is employed. They are generally placed inside the stand of the coil.

126. **Interruptors.**—Two types of interruptors may be employed for large coils; mechanical and electrolytic.

127. **Mechanical interruptors.**—Mechanical interruptors may be subdivided into several groups.

(1) Those in which the break is made between two metal surfaces, as in the old form of trembler or in the improved form of platinum break attached to large coils.

If the break occurs sharply when the hammer is moving with the greatest velocity and not at the end of its path, as in *Charpentier's* atonic interruptor, it will work satisfactorily in air. In *Radiguet's* interruptor the two copper surfaces of contact are immersed in petroleum.

(2) In the second class of interruptors a metal rod is immersed in a vessel of mercury, with a layer of alcohol or petroleum covering its surface.

A vertical up-and-down motion is imparted to the metallic rod by means of a rotary motor, or by the electrically sustained vibration of a tuning fork. Almost every electrical instrument maker has his own form of interruptor. For working from an alternating current *Villard's* interruptor is very convenient. (55.)

(3) The third class consists of mercury interruptors. Further descriptions of the numerous forms of these instruments may be found in the catalogue of any instrument maker. Any one of them is suitable for the production of high frequency currents.

128. **Electrolytic interruptors.** *Wehnelt's* electrolytic break consists of a vessel filled with a ten per cent solution of H_2SO_4. A platinum wire, surrounded by a glass tube, except just at the tip, dips into this solution and is connected to the positive lead of an electrical source, giving a pressure of 110 volts.

An electrode of some metal such as lead, which is not attacked by the acid, is immersed in another part of the vessel. When the current passes the water is decomposed, and this is accompanied by an evolution of heat which sets up the phenomenon known as *calefaction.* The bubbles of oxygen collected round the heated platinum point form a non-conducting sheath which interrupts the circuit. The moment the current is arrested the bubbles cease to form, contact is made between the liquid and the wire, and the current passes once more.

The current may be regulated by altering the length of platinum wire in contact with the water, or a rheostat may be introduced into the circuit. *Wehnelt's* interruptor may also be used with accumulators, but in that case a very large current is required and the electrolyte should be warmed.

The composition of the electrolyte and the arrangement of the electrodes has been modified by different makers. A condensor is not required for the induction coil when a Wehnelt interruptor is used.

The self-induction of the primary should be less with an electrolytic interruptor than with the slower mechanical interruptors. The less the coefficient of self-induction of the primary, the less will be the difference between the make and

break currents in the secondary. It is the self-induction which retards the current of make and enforces the current of break in the primary. The ordinary induction coil has an average coefficient of self-induction which will allow of its being used with either form of interruptor.

Coils are also made with variable self-induction, the primary consisting of two separate coils, as in the *Radiguet* induction coil of 1902. These are much to be preferred for medical use.

129. **Current transformers for high frequency currents.**—An alternating current supply may be used directly for the production of high frequency currents. The original arrangement has been much improved lately by the apparatus designed by *Messrs. Gaiffe.* A transformer with closed magnetic circuit is employed to raise the potential from 110 volts to 15,000 volts. This high tension alternating current can then be used directly to charge the high frequency condensors.

We only require to convey just sufficient charge to the condensor to cause a spark to pass across the detonator gap, and therefore if one wave of the alternating current brings sufficient electricity at a potential high enough to reach this limit, we shall get a spark for every wave or semi-period.

With the alternating current supplied to Paris this would mean 84 discharges per second. In practice we generally get more than one spark per wave, since the capacity of the Leyden jars is small compared to the charge of each phase of the alternating current.

This arrangement has two disadvantages. A permanent arc is often established between the knobs of the spark gap unless some means are adopted to suppress it. The most efficacious of the devices designed for this purpose is to blow out the arc by a current of air. The second disadvantage is that the waves of high frequency are reflected back-

wards into the secondary circuit, and injure the transformer. This makes it impossible to employ a higher pressure than 15,000 volts, which is insufficient to yield results that are really satisfactory.

At *Prof. d'Arsonval's* suggestion *Messrs. Gaiffe*, of Paris, have lately devised an instrument far in advance of anything obtainable before. The principal improvement is the employment of a special apparatus which prevents this backward flow of the high frequency waves.

In Fig. 24, SS' is the secondary of a transformer capable of raising the potential of the current supplied by the alternating current mains from 110 volts to 60,000 volts. LL' are Leyden jars whose inner coatings are connected with

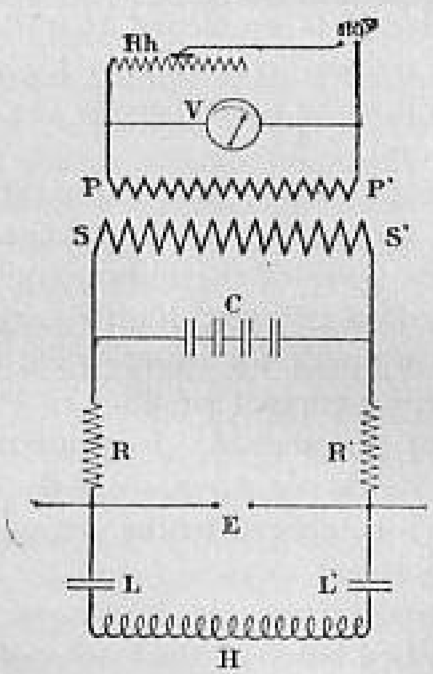

Fig. 24.

SS'. A spark gap E is interposed in this circuit. The outer coatings of the Leyden jars are connected to a self-induction

coil H. The condensor C and the liquid resistance RR' are designed to prevent the return of high frequency waves to the coil. These would subject the contiguous spirals of the secondary to differences of potential greater than the insulating material can stand, and the insulation would be injured. The liquid resistances RR', each of about 150,000 ohms, are introduced in the leads between the coil and the Leyden jars. A multiple plate condensor C is placed in parallel with these resistances.

The chief purpose of the liquid resistances is to avoid the formation of an arc, while the condensor prevents the return of the high frequency waves.

This apparatus is equally suitable for high frequency and for X-ray work, and is a real advance in the construction of apparatus for medical purposes.

III.—Employment of high frequency currents.

130. **Methods of employing High Frequency Currents.** High frequency currents may either be employed directly by allowing the current to pass through the body as described in paragraph 131, or by *d'Arsonval's* auto-conduction method, in which the enormous inductive force of the high frequency current is used to induce auto-conduction currents in the human body.

High frequency currents may also be utilised for effleuvation. This is done by inducing similar currents in a neighbouring circuit; these currents will have an augmented potential due to the effects of resonance in the circuits. (138.)

131. **Direct application.**—If we attach a rheophore to each end of the self-induction coil in *d'Arsonval's* apparatus, and connect these to a body of high resistance, the high frequency current will pass through the body in preference to going through the coil, in consequence of the large

resistance to oscillating currents offered by the self-induction of the latter.

Thus if the patient's body is placed in parallel with the self-induction coil the high frequency currents will pass through it, while the coil will act as a sort of lightning conductor, offering an alternative route to the currents of low frequency, which will pass by preference through the less resisting metallic conductor.

Direct applications of high frequency currents may be *stabile* or *labile*. They are called stabile when the electrodes, either bare or covered with wet cloth, are applied firmly to one spot. When, on the contrary, the electrodes are constantly moved from place to place over the region to be treated the application is said to be labile.

Another method of direct application of high frequency currents is the so-called *electrification by condensation*, in which one end only of the coil is connected to the patient. For this purpose a couch is used having an insulated mattress, under which is a large sheet of lead. This is connected to one end of a d'Arsonval helix.

The patient, placed on the couch, holds in his hand an electrode connected to the other end of the helix. A condensor is thus formed, in which the mattress is the dielectric and the lead sheet and the patient form the two armatures. This condensor is charged and discharged with every alternation of the current.

The precise interpretation of the phenomena of high frequency condensation is not as yet satisfactorily explained.

132. **Auto-conduction, d'Arsonval's method.** — Any conductor placed within an enveloping high frequency circuit becomes the seat of currents of auto-conduction similar to Foucault currents.

These currents of auto-conduction may be demonstrated by forming an electric circuit with a lamp and a coil of wire,

and placing this within a large d'Arsonval solenoid. The lamp will become incandescent when the high frequency current is turned on.

Currents of auto-conduction in the living body may be demonstrated by bending the arms in a circle concentric with the high frequency circuit and holding a lamp of low voltage between the two hands. The experiment will be more successful if the hands have been previously dipped in a slightly alkaline solution of sal ammoniac. The lamp will glow when high frequency currents are passed.

In practise treatment by means of auto-conduction is given in two ways:—

(1) By placing the patient inside d'Arsonval's large solenoid made of thick copper wire or copper ribbon. The oscillating currents caused by the discharge of the condensor traverse the whole length of this coil.

(2) By placing the patient between two flat spirals which are wound in the same direction and traversed by high frequency currents passing in the same direction. (138.)

133. **Oudin's Resonator.**—We may increase the potential of high frequency currents by means of a *resonator*. These are of two kinds, single pole resonators and resonators with two poles.

There are two varieties of single pole resonators—the helix and the flat spiral.

There are three varieties of bipolar resonators—the *d'Arsonval* helix, the *Oudin* resonator as modified by *O'Farrill*, *Lebailly* and *Rochefort*, and the flat spiral resonator.

134. **Oudin's unipolar resonator.**—*Oudin's* first resonator was formed of a helix of copper wire, a point near one end of which was connected to one extremity of a d'Arsonval coil. (124.) The effleuves were given off from the opposite extremity of the resonator.

When the lower end of the helix was connected to the other end of the self-induction coil the effects were improved, and these were still better when the self-induction coil was

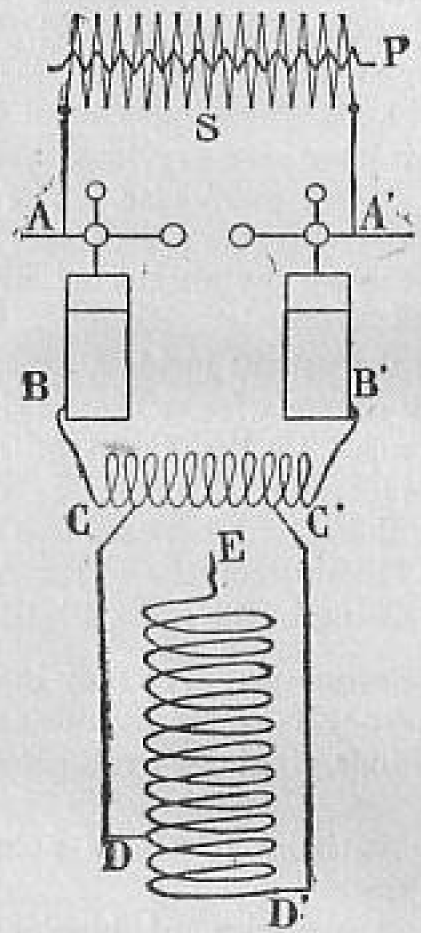

Fig. 25.—Oudin's unipolar resonator.

entirely suppressed. This is the form ultimately adopted by *Oudin*. (Fig. 25.)

The improved form of *Oudin's* resonator is therefore a helix of copper wire 2½ mm. in diameter, consisting of 50 turns with a distance of 8 mm. between each turn.

In this helix the current due to the discharge of the

Leyden jars circulates through three or four of the lowest coils. Phenomena both of induction and of resonance result; induction effects due to the influence of the lower coils on the upper portion of the helix, and resonance effects in the upper portion.

This phenomenon of reinforcement is called resonance from its analogy with acoustic resonance, since the quantity of the effleuve may be increased by tuning the helix to correspond with the exciting coil. This is done by adjusting its coefficient of self-induction.

135. **Guilleminot's flat spirals for high frequency.**—In-

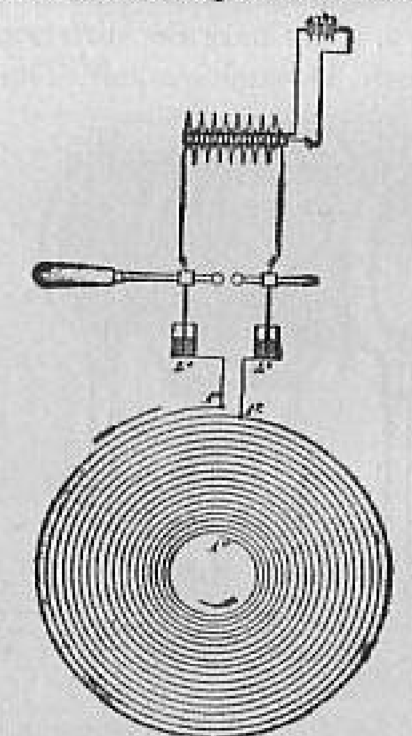

Fig. 26.—Guilleminot's high frequency spiral.

stead of a helix we may use a flat spiral.[1] The author's form of spiral resonator is so constructed that the excitation is

[1] H. Guilleminot, Archives d'electricité Médicale, 1901, No. 287.

caused by a single turn, the outer one, which acts as the inducing spiral.

In practise the adjustment is not made by altering the coefficient of self-induction of the inducing spiral. This is kept constant and a subsidiary coil of thick wire, with an apparatus for regulating its self-induction, is introduced into the exciting circuit.[1]

The spiral is formed of 18 turns of wire, 2 mm. thick, held in place by radii of catgut. The smallest circle has a diameter of 33 cm., and the largest a diameter of 83 cm. The interspaces between successive turns increase in width towards the periphery, since here the difference of potential between successive turns is much greater. The various forms

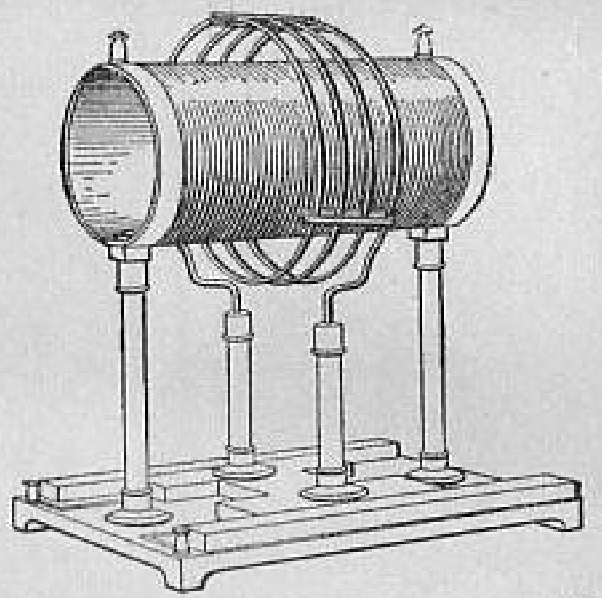

Fig. 27.—The d'Arsonval resonator coil.

of exciter used in applying high frequency currents in medicine are attached to the centre of the spiral.

136. **Bipolar resonators—The d' Arsonval coil.**—The d'Arsonval coil consists of a helix of fine wire wound on a

[1] H. Guilleminot, Academie des sciences, 1902.

cylinder which carries the induced current. Around this at a distance of several centimetres are three or four turns of thick wire, which can be moved along the cylinder so as to be placed at either end or in the middle of the fine-wire helix.

Suppose the thick coils to be placed around the middle of the cylinder, as in Fig. 27. Effleuves of equal strength will

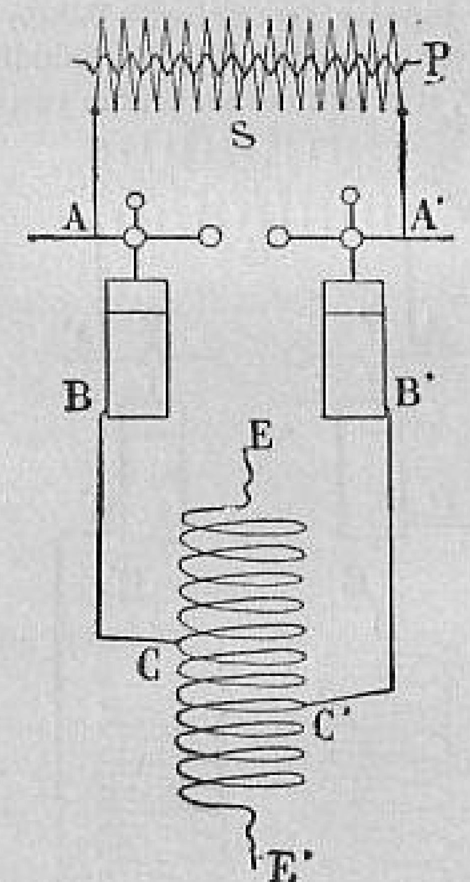

Fig. 28.—Bipolar resonator, O'Farril and Lebailly type.

be given off from both ends of the helix, and these will mutually attract each other.

This is termed the bipolar effleuve. At any given moment

the two effleuves will be of opposite signs, the signs changing simultaneously when the direction of the current changes, which it does some thousand million times per second.

If the inducing coil is pushed towards one end the effleuve at that end will decrease to nil, and the coil will act as an unipolar resonator.

137. **Oudin's bipolar resonator.**—When the inducing coil of a d'Arsonval resonator is in the middle of the cylinder, as in Fig. 27, it resembles an Oudin resonator with the

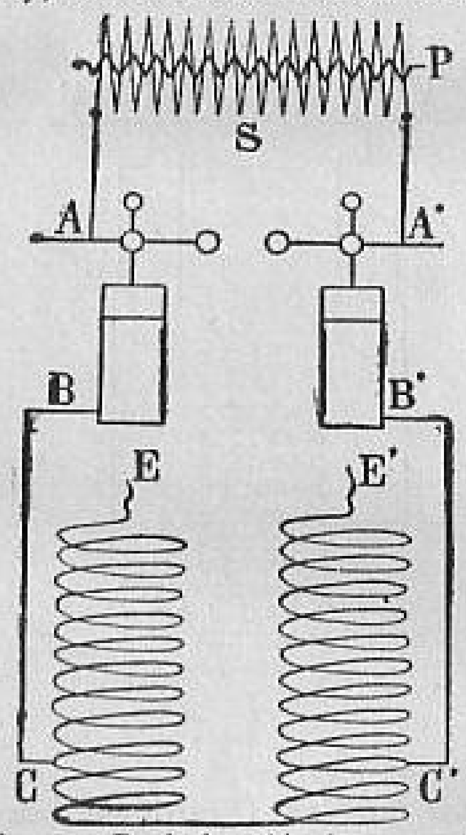

Fig. 29.—Rochefort bipolar resonator.

inducing current applied to its central portion which is insulated from the rest.

If the central portion of the main coil itself is used

for the inducing current, we get the *O'Farril* and *Lebailly* type of resonator, which is merely an Oudin resonator excited by means of its own median coils. Fig. 28.

If we duplicate the resonator in the above type we get the *Rochefort* resonator; Fig. 29 is not an exact representation of *Rochefort's* arrangement, since he uses two pair of condensors, one for each solenoid, but it shows clearly the relationship between this and the previous types.

Different effects are obtained according to the direction of the discharge in the inducing coils.

If B be the positive and B' the negative armature of the condensors, bipolar effleuves will be obtained only when the current from B enters the first helix at the median point C, and leaves it at the extremity, whilst it enters the second helix at the extremity and leaves at the median point C'.

If the positive armature were connected to the extremities of both coils, or to the median points of both coils, the resulting effleuves would repel and not attract one another.

138. **Bipolar effleuves obtained from flat spirals.**—Spiral resonators are better adapted for studying bipolar effects. In this case we have to take into account the mode of coupling the spirals and the mutual influence of one spiral on its neighbour.

(1) Bipolar effects obtained by coupling. In the high frequency condensors, we may consider the direction of the discharge to be from the external positive armature of one condensor to the external negative armature of the other condensor.

We get a bipolar effleuve of opposite signs when this current is made to pass centripetally through one spiral

and centrifugally through the other. If the effleuve producing poles of the two spirals are now connected, the effleuvation will cease.

Effleuves of the same sign will be obtained from both poles if the current circulates centripetally in both spirals, or centrifugally in both. If now the two effleuve producing poles are connected, the effleuves are not neutralised but reinforce one another.

(2) Bipolar effects may also be obtained by the influence of one spiral on another in its neighbourhood if

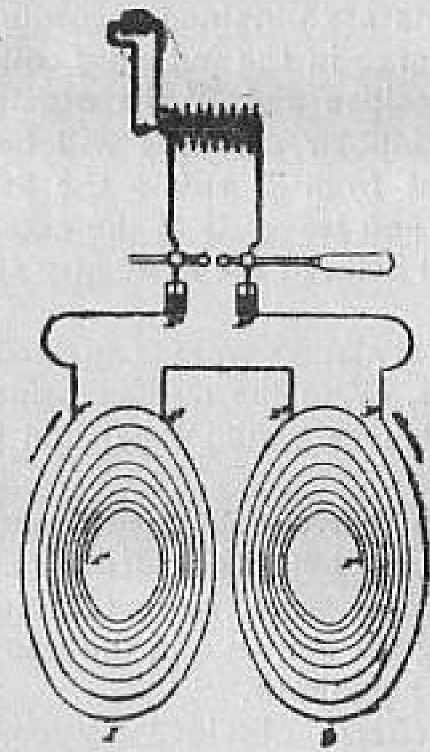

Fig. 30.—Guilleminot's spiral resonator. Inverse coupling for obtaining bipolarity.

we connect only one spiral in the condensor circuit, and place another insulated spiral opposite to it. When the current passes through the first spiral, the central pole of

the insulated spiral will give out effleuves of the same sign if its windings are in the same direction, and effleuves of opposite sign if its windings are in the opposite direction.

There are several ways of using flat spirals for medical purposes.

(1) *Use of two spirals to give a bipolar effleuve* (Fig. 30).—Place the two spirals parallel, so that one spiral is right handed and the other left handed.

Connect A'B', the outer extremities of the spirals, to LL', the external coatings of the two Leyden jars, and connect the two median points together by a flexible wire. These median points A" B" mark the boundary of the inducing and induced currents and are at the completion of the first turn of the spiral.

(2) *Arrangement of two spirals to produce effleuves from a body interposed between them.*—Place the two spirals parallel to each other with their windings in the same direction.

Connect the terminal of one condensor with the outer extremity of the first spiral; connect the median point of the first spiral with the outer extremity of the second spiral; connect the median point of the second spiral with the terminal of the second condensor.

With this arrangement the effleuves will repel each other, but an object placed between them will pour effleuves towards both spirals.

(3) *Employment of two flat spirals for auto-conduction.* The two spirals wound in the same direction are arranged as before, but instead of only one turn, 8 to 12 turns of the spiral are made use of for the inducing current.

Under these circumstances there are no effleuves, but intense auto-conduction effects are produced in any body of sufficient capacity interposed between the terminals.

139. **High frequency electrodes or exciters.**—The

form of exciter used depends on the kind of high frequency treatment required.

1. *Direct application.*—For this purpose uncovered metal electrodes are used. These may be of various shapes, plates, buttons, cylindrical handles, or the special conical electrodes devised by *Doumer.*

2. *Direct application with the interposition of a sheet of glass.*—For this the so-called condensing electrodes of *Oudin* are used.

3. *Sparking.*—When it is desired to produce sparks blunt points or balls are used.

4. *Effleuvation.*—The most suitable exciters for producing effleuves are the metallic pencil, the brush, the multiple-point, the cup, or other electrode with an extended discharging surface.

140. **Measurement of High Frequnecy Currents.**—High frequency currents may be measured by means of the thermic galvanometer. Since the current is an alternating one we can only measure the efficient intensity, *i.e.,* the intensity of a continuous current which would give the same thermal effects.

The thermic galvanometer is an instrument for measuring the elongation of a wire, due to the heating effect of the current which passes through it.

We may also use the induction amperemeter devised by *Gaiffe* and *Meylan.* This measures the repulsive force between the original current and the current which it induces in a coil attached to the indicator.[1]

The thermic galvanometer is placed in series in the circuit. It is the only type in practical use. It is only employed when we are using the direct application of high frequency currents; for auto-conduction no instrument for measuring the current is of any practical value.

[1] Dénoyes. Les courants de haute frequence, Montpelier.

CHAPTER V.

STATIC ELECTRICITY.

I. General Considerations.

141. **Definition.**—The fact that under the influence of friction certain substances, such as amber, will attract light bodies, was known to the ancient Greeks.

Resin, glass and many other substances possess this property, which may even be observed in metals, provided that they are suitably supported by a handle of glass or other insulating material. If, however, they are touched with a wire connected to earth, metals at once lose this property of attraction.

Bodies like amber, resin, glass, or insulated metal are said to be *electrified* by the friction, and the electricity which remains on the body is termed *static electricity.* The phenomenon which takes place along the metal wire connected to earth is an exhibition of *dynamic electricity.* If by some means the electrified body could have its electric charge replaced as fast as it was removed by the wire connected to earth, we should have a constant electric current along that wire. A body charged with electricity may be compared to a reservoir full of water having no outlet, while the electric current corresponds to the flow of water through the conduit pipes.

A body charged with electricity has certain mechanical properties, the manifestation of which leaves its electric mass unaltered. An electric current, on the other hand, has properties due to the transmission of a charge or

The break spark will therefore in this case only correspond to an energy of 262 watts.[1]

This spark moreover will find an alternative route through the main circuit, and its effect on the interruptor will therefore be reduced to a minimum.

The usual method of arrangement in the potential reducer is to use an invariable resistance of 10 to 20 ohms in the main circuit, and to place the cautery in parallel with an adjustable resistance of 3 to 5 ohms.

[1] Let I^c be the current through the cautery and R^c its resistance,—I^s the current through the shunt, and R^s its resistance. In the above example $I^s R^s = I^c R^c = 3$ volts, since the current I^c is 10 amperes and the resistance R^c is .3 ohms. If I^s the current through the shunt is 1 ampere, R^s must be 3 ohms. R, the equivalent resistance of R^s and R^c, is therefore .273 ohms. The resistance of the rest of the circuit is $10 - .273 = 9.727$ ohms. If to this be added the resistance $R^s = 3$ ohms, we get a total resistance of 12.73 ohms when the cautery is not in use.

CHAPTER VIII.

OZONISATION.

222. **Method of producing ozone.**—Ozone (οζη, odour) is an allotropic modification of oxygen. Whereas the oxygen molecules O_2 consists of two atoms of oxygen, the ozone molecule O_3 contains three such atoms. The earliest observations on ozone were made by *Van Marum* in 1779, and *Schoenbein* in 1840.

Ozone, which exists in small quantities in the atmosphere, may be produced artificially by several methods, the most practical of which is electricity. The effleuve discharge, in air or oxygen, of conductors charged to a high potential is accompanied by a production of ozone.

Berthelot's ozone generator is the one generally used in the laboratory. It consists of a glass tube filled with dilute sulphuric acid, surrounded by a second tube dipping into a shallow vessel filled with the same solution. The space between the two tubes is traversed by a current of air or oxygen. A current from an induction coil is passed through the apparatus, one terminal being connected to the solution in the inner tube, and the other to that in the shallow vessel. Electric discharges occur across the space between the tubes and thus convert part of the oxygen into ozone.

The generators of ozone used in medicine are of three types, the *Houzeau* generator, electrostatic generators, and high frequency generators.

223. **Ozone generators of Houzeau, Labbé, and Oudin.**—All these make use of the discharges from an induction coil for the production of ozone. A glass tube covered with

aluminium foil or aluminium wire, is connected with one terminal of an induction coil. An aluminium rod connected

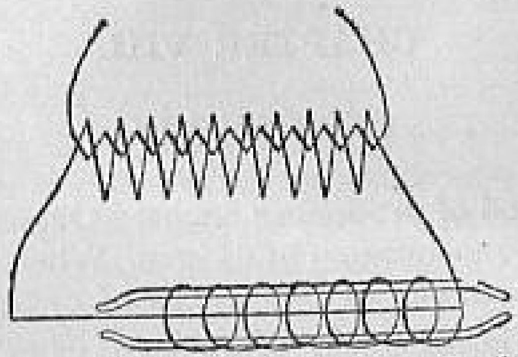

Fig. 41.—Ozone generator, Houzeau-Oudin type.

to the other terminal of the coil passes down the centre of the tube. Aluminium is chosen, since it is less readily oxidisable than most metals.

The output of ozone is very small. *Bordier* has shown that although the presence of ozone can be distinctly recognised by the smell, the amount is so minute as to be practically useless for physiological or therapeutic work.

224. **Electrostatic ozone generators.**—There is a noticeable production of ozone at the poles of an electrostatic machine. *Bordier's* experiments, however, show that with a Wimshurst machine of medium size, only a fraction of a millegramme of ozone is generated in an hour. The same quantity is produced at both poles, and is proportional to the output of the machine.

In *Weill's* electrostatic ozonator a metallic rod furnished with a number of radiating points is enclosed in a barrel-shaped glass vessel. The latter is covered with tin-foil to about three-quarters of its height. A current of air is passed through the vessel.

The central rod is connected to the outer armature of the Leyden jar on the negative pole of a Wimshurst machine. The outer tin-foil covering of the ozonator is earthed, as is

also the external armature of the Leyden jar on the positive pole of the static machine. The arrangement, therefore, unites the advantages of electrostatic and of high frequency ozonators.

225. **High frequency ozone-generators.**—*Bordier's* investigations have proved the superiority of high frequency currents for the production of ozone. The effleuve from an Oudin resonator, or from a flat spiral, is used to convert the surrounding oxygen into ozone.

When an Oudin resonator is used, it is covered with a glass globe within which the air or oxygen circulates. The more rapid the flow of air through the glass the greater will be the production of ozone. (*Bordier.*) When high fre-

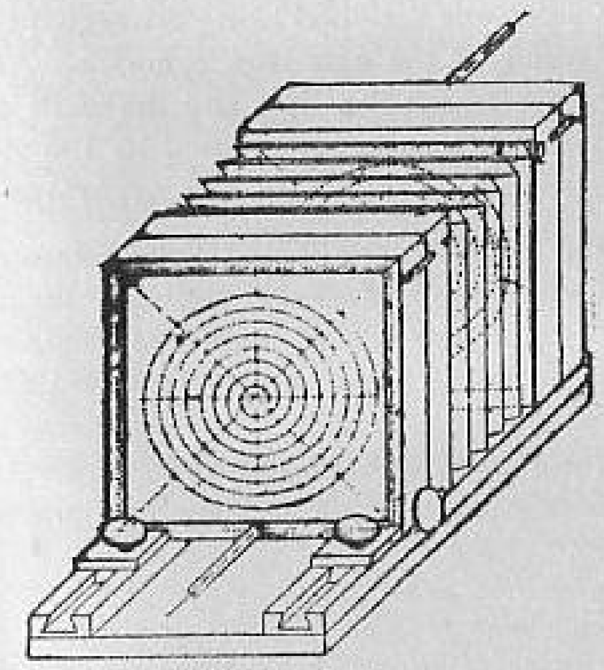

Fig. 42.—Guilleminot's Ozone generator.

quency spirals are used the bipolar arrangement is employed, the coils being enclosed in a box having glass ends and collapsible sides, as in Fig. 42.

The silent effleuve should be used and sparking should be avoided in order to prevent the production of nitrous acid. The nature of the interruptor has a great influence on the efficiency of the apparatus. *Wehnelt's* interruptor, as modified by *Bordier*, gives most excellent results.

226. **Otto's rotary ozone generator.**—At the meeting of the French Society of Civil Engineers in 1901, *Otto* described a rotary ozone generator with movable electrodes. It consists of a cylindrical vessel of cast iron, closed at both ends by plates of glass. Within this vessel a number of thin steel discs with gaps cut in their edges are mounted on an insulated axis.

An alternating current transformer is used, giving a current of 20,000 volts, one terminal being connected to the steel discs and the other to the cast iron cylinder. An arc discharge is formed between the discs and the walls of the cylinder, but this is continually interrupted by the gaps in the edges of the rotating discs. With this apparatus a considerable quantity of ozone is obtainable.

CHAPTER IX.

ELECTRICITY AS A GENERATOR OF MOTION—VIBRATORY MASSAGE—PASSIVE GYMNASTICS, ETC.

227. **Vibrotherapy.**—Electricity is also used to produce the various forms of movement used in vibrotherapy and sismotherapy. The latter term was introduced by *Jayle* and *Lacroix* to designate the mode of treatment by means of an apparatus producing mechanical vibrations. The apparatus consists either of a tuning fork with electrically maintained vibrations, or a rotary excentric vibrator driven by a dynamo.

Two types are employed. In the first the motion is conveyed to the vibrator by means of a flexible axis. In the second a small motor is placed within the vibrator itself.

The former type is the more powerful and more easy to regulate, but it is less convenient, since in many positions the flexible axis is difficult to adjust.

Vibrating drums, vibrating chains, etc., are all worked on the same principal.

Passive movements of the limbs may also be obtained by means of apparatus driven by electrical energy.